Description of LES arctic stable boundary layer case for GABLS

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Introduction

This case is based on the simulations presented by Kosovic and Curry (JAS 2000, Vol 57, 1052-1068). The boundary layer is driven by an imposed, uniform geostrophic wind, with a specified surface cooling rate and attains a quasi-steady state with a depth of between 150 and 250m. Integrations carried out with the Met Office LES model have shown a large sensitivity of this case to resolution, subgrid model and numerical advection scheme, even in quantities such as the mean profiles. The basic aim of the intercomparison is to contribute towards a quantification of the reliability of stable boundary LES. With this in mind, where a participant's model has options for different subgrid models or numerical schemes, parallel runs with the different options would be most useful.

Description

- Domain: 400m x 400m x 400m
- Grid: as a minimum, all participants should run with 6.25m x 6.25m x 6.25m but it is highly desirable that runs with 3.125m grids should also be carried out. If it is feasible for participants to carry out runs at yet higher resolution, these would also be very useful. Runs of the Met Office LES model using 2m and hopefully also 1m grids will be available as high-resolution reference solutions. It is also of interest to see how models behave at poor resolution, so results from runs with a 12.5m grid may also be submitted. Some models may tend to laminarize at that resolution, although adjustments to the subgrid model may, in some circumstances, help with this problem.
- Geostrophic wind: U_g=8m/s, V_g=0m/s, f=1.39e-04 (corresponding to latitude $73°N$)
- Initial mean state: $u = U_g$, $v = V_g$ for z>0m. θ=265K for $0m \leq z \leq 100m$, then increasing at 0.01K/m to domain top, where the potential temperature is thus 268K.

- Initial perturbation: random noise with an amplitude of 0.1K on the θ field for $0m \leq z \leq 50m$. For models requiring an initial subgrid TKE field, set equal to $0.4(1 - z/250)^3 m^2/s^2$ for $0m \leq z \leq 250m$ and zero above that.

- Surface boundary conditions: w=0, no-slip, with surface temperature specified as 265K initially, decreasing continuously at a rate of 0.25K/h. Value of z_0 set to 0.1m for both momentum and temperature. If the boundary condition is implemented through surface similarity theory then, if possible, use the similarity functions below:

$$\frac{\partial u}{\partial z} = \frac{u_*}{\kappa z}(1 + \beta_m \frac{z}{L})$$

$$\frac{\partial v}{\partial z} = \frac{u_*}{\kappa z}(1 + \beta_m \frac{z}{L})$$

$$\frac{\partial \theta}{\partial z} = \frac{\theta_*}{\kappa z}(1 + \beta_h \frac{z}{L})$$

  with $\kappa = 0.4$, $\beta_m = 4.8$, $\beta_h = 7.8$. See below for the definitions of L, u_* and θ_*.

- Upper boundary condition: free slip, $w = 0$.

- Lateral boundary condition: periodicity.

- Damping layer: above 300m (desirable).

- Other constants (if required): $g = 9.81$, reference potential temperature $\theta_0 = 263.5K$, reference density $\rho_0 = 1.3223 kg/m^3$.

Definitions for diagnostics

- Coordinate directions: $x_1 = x$, $x_2 = y$, $x_3 = z$

- Velocity components: $u_1 = u$, $u_2 = v$, $u_3 = w$

- Deviation of pressure from hydrostatic value: p'

- Horizontal domain- and time-average of any variable is denoted by an overbar

- $u_i = \overline{u_i} + u_i'$ with $\overline{u_3} = \overline{w} = 0$

- Subgrid stress tensor: $\tau_{ij} = \rho_0 \nu S_{ij}$, where ν is the eddy viscosity

- $S_{ij} = \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}$

- Square of the modulus of stress tensor: $S^2 = \|S_{ij}\|/2$

- Mean turbulent kinetic energy: $\bar{q} = \overline{u_i^2}/2$

- Friction velocity: $u_* = (\overline{u'w'}_s^2 + \overline{v'w'}_s^2)^{1/4}$ where the subscript s indicates a value at the surface ($z = 0$)
- Surface turbulent temperature scale: $\theta_* = -\overline{w'\theta'}_s / u_*$
- Monin-Obukhov length: $L = u_*^2 / \left(\kappa \frac{g\theta_*}{\theta_0}\right)$
- Time tendency of TKE: $TEND = \frac{\partial \overline{q}}{\partial t}$
- Resolved shear production of TKE: $RSPROD = -\overline{u_i' w} \frac{\partial \overline{u_i}}{\partial z}$, $i = 1, 2$
- Subgrid shear production of TKE: $SSPROD = \overline{\tau}_{i3} \frac{\partial \overline{u_i}}{\partial z}$, $i = 1, 2$
- Total transport of TKE: $TTRAN = \frac{1}{\rho_0} \left(\frac{\partial(\overline{u_i' \tau}_{i3})}{\partial z} - \frac{\partial(\overline{wp'})}{\partial z} \right) - \frac{\partial(\overline{wq})}{\partial z}$, $i = 1, 2$
- Buoyancy production of TKE: $BPROD = \frac{g}{\theta_0} \overline{w\theta'}$
- Dissipation: $DISS = \nu S^2$

Output required

The integration is to be run for 9 hours (32400s) with datasets A,B,C and D provided for two 1-hour averaging periods (7-8 hours and 8-9 hours) and identified as A8, A9 etc. Dataset E contains timeseries over the whole run, preferably with a sampling interval of 1 minute, although this is not critical. The boundary layer height is to be diagnosed as the height at which $(\overline{u'w'}^2 + \overline{v'w'}^2)^{1/2}$ falls to 5% of its surface value (u_*^2), divided by 0.95.

For each of sets A, B, C and D, please interpolate each of the variables to the common vertical grid locations specified in variable 1 of each set, if necessary. The heights at which the variables locate do not have to be the same across all sets, however. Please provide each set as a separate formatted data file, the first record containing an string of up to 130 characters, giving your name and any identifying details for the run. The second record should contain a single integer giving the number of elements in each of the succeeding records (ie the number of levels, or times for Set E, for which the diagnostics are provided). Each variable of the set should then be written out as a separate record, using 10E15.7 as the format for the WRITE statement. If a variable is not available, please set its values to -0.9999999E+07.

The data should be sent by email to malcolm.macvean@metoffice.com by 31 May 2003.

Set A - Mean profiles

1. Height at which variables in this set locate (m)
2. x-velocity: $\overline{u}$ (m/s)

3. y-velocity: $\overline{v}$ (m/s)
4. Potential temperature: $\overline{\theta}$ (K)

Set B - Variances

1. Height at which variables in this set locate (m)
2. Resolved u-variance: $\overline{u'^2}$ (m^2/s^2)
3. Resolved v-variance: $\overline{v'^2}$ (m^2/s^2)
4. Resolved w-variance: $\overline{w'^2}$ (m^2/s^2)
5. Resolved skewness: $\overline{w'^3}/\overline{w'^2}^{3/2}$ (dimensionless)
6. Subgrid TKE (m^2/s^2)
7. Resolved potential temperature variance: $\overline{\theta'^2}$ (K^2)

Set C - Fluxes

1. Height at which variables in this set locate (m)
2. Resolved x-momentum flux: $\overline{u'w'}$ (m^2/s^2)
3. Subgrid x-momentum flux (m^2/s^2)
4. Resolved y-momentum flux: $\overline{v'w'}$ (m^2/s^2)
5. Subgrid y-momentum flux (m^2/s^2)
6. Resolved vertical (w) potential temperature flux: $\overline{w'\theta'}$ (Km/s)
7. Subgrid vertical (w) potential temperature flux (Km/s)
8. Resolved horizontal (u) potential temperature flux: $\overline{u'\theta'}$ (Km/s)
9. Subgrid horizontal (u) potential temperature flux (Km/s)
10. Resolved horizontal (v) potential temperature flux: $\overline{v'\theta'}$ (Km/s)
11. Subgrid horizontal (v) potential temperature flux (Km/s)

Set D - Resolved TKE budget (items 2-7 have units of (m^2/s^3) **)**

These are the terms in the TKE budget which, in terms of the earlier definitions, may be written:

$$TEND = RSPROD + TTRAN + BPROD - DISS + SSPROD$$

It may be necessary to alter some of the definitions to reflect the way your model is formulated but try to split the terms up in the way indicated, if at all possible. The important thing is to present a consistent budget, preferably with zero residual.

1. Height at which variables in this set locate (m)
2. Resolved shear production: $RSPROD$
3. Subgrid shear production: $SSPROD$
4. Resolved buoyancy production: $BPROD$
5. Total transport: $TTRAN$
6. Dissipation: $DISS$
7. Storage: $TEND$=(TKE(end of hour) - TKE(start of hour))/3600.

Set E - Time series

1. Time (s)
2. Boundary layer height: h (m)
3. Surface potential temperature flux: $\overline{w\theta'}_s (Km/s)$
4. Friction velocity: u_* (m/s)
5. Monin-Obukhov length: L (m)
6. Maximum (over all gridpoints) of the absolute value of the vertical velocity (m/s)